THE RF SYSTEM OF THE SESAME STORAGE RING

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Abstract

SESAME the Synchrotron Radiation Light Source in Allan (Jordan) consists of a 22 MeV Microtron, an 800 MeV Booster Synchrotron (originally from BESSY I, Berlin, Germany) and a 2.5 GeV Storage Ring (new design). The RF system consists of four 500 MHz ELETTRA cavities powered by four 80 kW Solid State Amplifiers whereas the first amplifier is produced by SOLEIL and the other three are produced by SIGMA-PHI. The RF plant is controlled by the digital Low Level Electronics from DIMTEL. The system has been installed end of 2016. This report describes the setup of the facility and the results of the commissioning.

INTRODUCTION

The SESAME storage ring RF system main parameters are given in Table 1.

Table 1: Main RF Parameters

Energy	GeV	2.5
Current	mA	300
Circumference	m	133.2
Harmonic No.		222
Energy Losses per turn	KeV	603
Momentum compaction		0.008
Energy Spread	%	0.1
Natural Emittance	nm.rad	26
Natural Chromaticities H/V		-20/-12

The four ELETTRA cavities are located in a four m long straight section. Figure 1 shows the RF plant system setup: the wave guides start from the amplifiers passing a chicane for shielding the ionizing radiation from the tunnel, going to the cavities in the tunnel as can be seen in Figure 2. The waveguides have been contributed from DESY.

Figure 1: Top view of SESAME RF plant.

CAVITIES

The cavity-system has been contributed from Italy. The Elettra cavity has the ability to control the HOM's by means of precision cavity temperature control (±0.05 C°), HOM plunger positioning and the cavity axial deformation. Table 2 shows the RF plant main specs. The first produced cavity was tested in the lab to characterize the HOM within a range of 2.5GHz, and the effect of the plunger for shifting of the HOM. Table 3 lists the main longitudinal and transverse modes.

Table 2: Main RF Plant Specs

No. of Cavities		4
Frequency	MHz	499.65 +/-1
Cavity Shunt Impedance	MΩ	3.3
Quality Factor		43000
Coupling Factor		1-2.8
Maximum Voltage	kV	650
Maximum Cavity Power	kW	66
Maximum Forward Power	kW	100

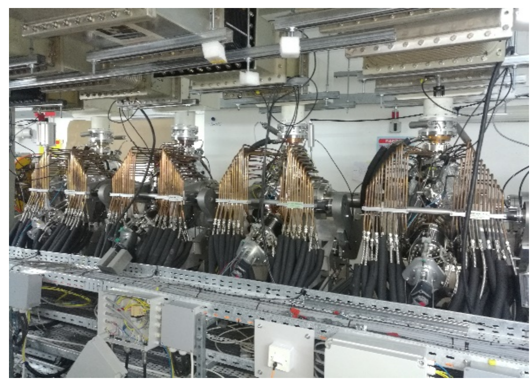

Figure 2: RF Cavities Section.

The formalism given in ref [1] and [2] had been used to calculate the growth rate of coupled bunch instabilities. The results are given in Figure 3 for the longitudinal and transversal modes.

Table 3: Cavity Modes

Mode	f res [MHz]	R/Q [Ω]	Q
L1	946.3	28.9	37000
L2	1056.5	0.7	40200
L3	1419.2	5	33300
L4	1510.3	4.9	27700
L5	1604.3	9	21000
L6	1875.2	0.3	31000
L7	1945	1.8	51500
L8	2075	0.1	22600
L9	2117.7	7.7	27000
Mode	f res [MHz]	R/Q[Ω]	Q
T1a	741.6	2.6	40000
T1b	741.7	2.6	40000
T2a	745.9	9	35000
T2b	745.9	9	36000
T3a	1112.6	10.1	36000
T3b	1112.7	10.1	37000
T5a	1242.1	2.8	17800
T5b	1242.9	2.8	17800

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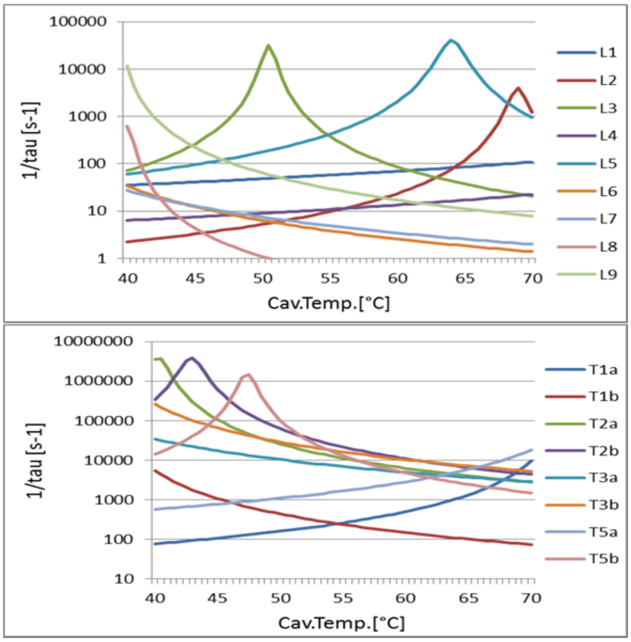

Figure 3: Grow rate of the longitudinal and transversal modes as a function of the cavity temperature.

SOLID STATE AMPLIFIERS

SOLEIL, who has done the pioneering work of developing Solid State Amplifier (SSA) for High Power RF at 350 MHz, agreed to develop such amplifiers for SESAME for operation at 500 MHz and built one amplifier for SESAME [3]. The latest 6th generation LDMOS (BLF578 from NXP is used. They further transferred license for manufacturing these SSA to SIGMAPHI [4], who manufactured further three units. Each SSA consists of combining 160+5 basic amplifiers, each module provides 600 W RF power at 16 dB gain and 65% efficiency at 1dB compression. The main parameters for these SSA are summarized in Table 4.

Table 4: SSA Specs

P_{out}	kW	80@50VDC
Total Gain	dB	77
Input Power	dBm	2
F_0	MHz	500
max. P_{ref}@ pulsed 10us	kW	80
max. P_{ref}@ CW	kW	30
Efficiency at full Power	%	53
Maximum harmonic content	dBc	-25
Maximum Phase Noise	dBc	-60

The layout of the SSA is given in Figure 4: The total number of RF modules is 160+5; eight modules are combined in one group whereas two groups are mounted on one cooled dissipater.

Five controllers are used for the SSA, each controller monitors four groups modules temperature and current, the forward and reflected power of each group, a sixth controller is used to monitor the SSA total forward and reflected power and the water flow. Critical parameters plus a PSS signal are used for interlocking the system.

LABVIEW is used for monitoring; Figure 6 shows the main menu.

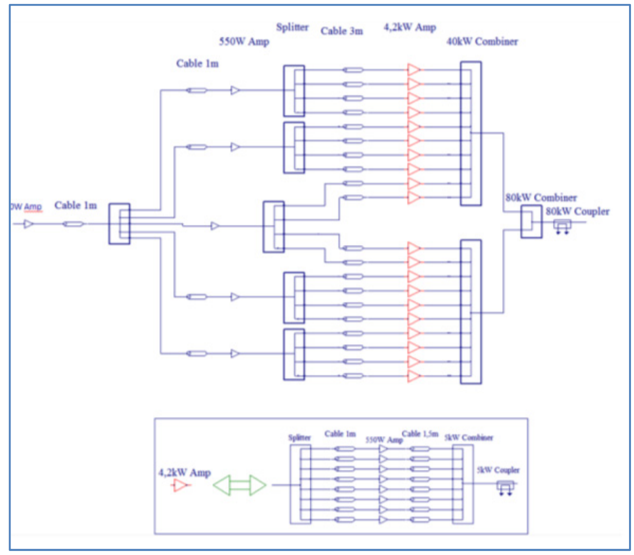

Figure 4: Layout of the SSA.

The 160kW DC power is delivered to the SSA through modular design of 5 x 16 + 3 2KW-AC/DC-50V power supplies from EATON (APR48), whereas each magazine of 16 units has its own controller which checks the voltage and current.

The gain and efficiency of the amplifier as a function of the output power for different DC voltages are shown in Figure 5.

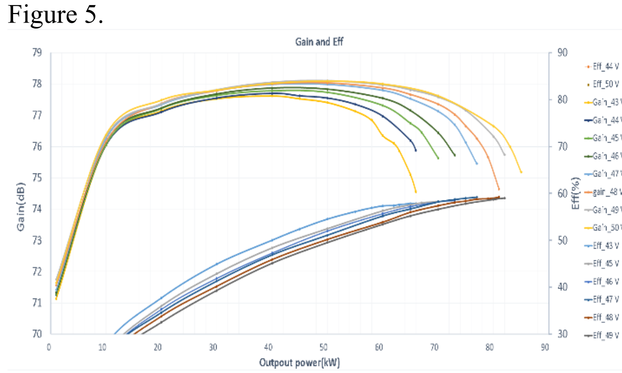

Figure 5: Gain and Efficiency of SSA.

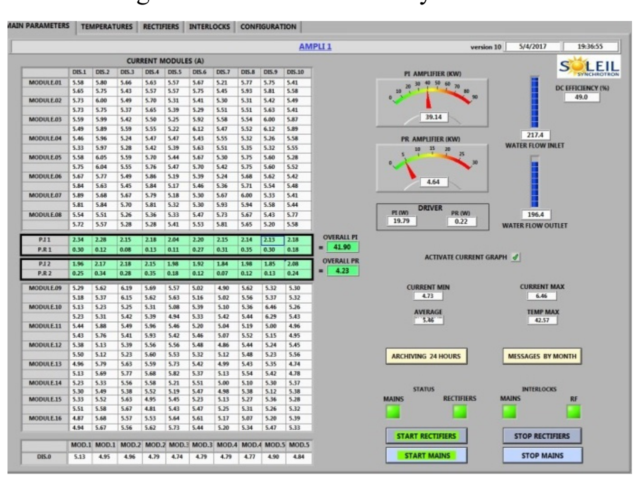

Figure 6: Main menu of the SSA.

D-LLRF

DIMTEL D-LLRF (LLRF9) [5] had been selected to control both the storage ring and booster RF. Two units are used to control the four storage ring cavities. Figure 7 gives the layout of the system.

Each unit has up to 9 Input signals, 2 x 3 of them (P_{for}, P_{ref}, U_{cav}) are used and two drive outputs (max 9 dBm). The signals are sampled at an intermedium frequency of 1/12 of the main (499.67 MHz). Additional slow inputs are used for monitoring vacuum and tuner position.

Communication with the motion control system, consisting of two axes Galil controller and two motor drives, is done by direct Ethernet connection.

A PI loop implemented inside the FPGA stabilizes the amplitude and phase of the cavity by correcting the amplitude and phase vector of the driving signal. To keep the cavity in resonance, a PI tuner loop compares forward and cavity phase and acts on the motion control system.

The system includes a network analyser for fast setting up of the parameters. Figure 8 shows the noise rejection response of the RF system. Furthermore, waveform acquisition can be used for analysis of signals (i.e. post mortem).

All input signals are interlocked in case exceeded the maximum level plus a further external interlock signal.

Excess to the units is done via EDM panels or CSS panel directly commuting with the Epics Process Variables.

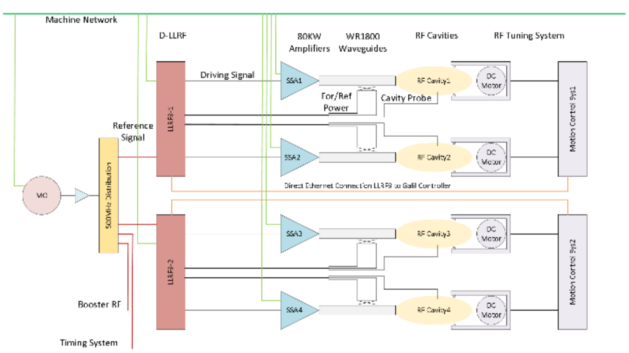

Figure 7: Layout of the digital low level RF.

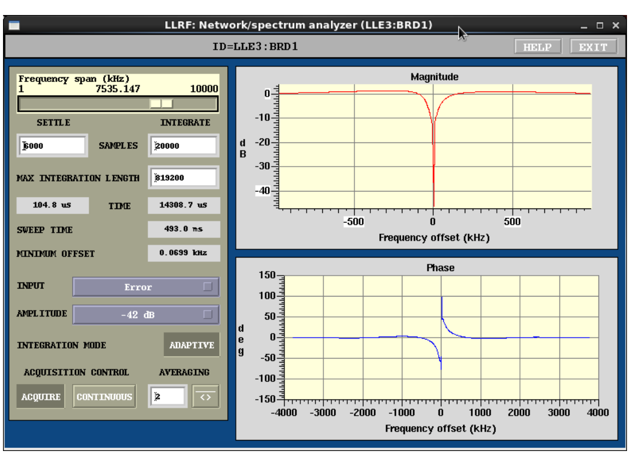

Figure 8: Rejection response of the RF system.

RF SYSTEM COMMISSIONING

The first two cavities and amplifier had been operational in Oct 2016. The setup of the D-LLRF without beam in the ring went smoothly without the least problem. Commissioning with beam and two cavities in operation started in Jan 2017. First beam could be accumulated at 0.8 GeV injection energy in Jan., ramping up to 2.0 GeV had been achieved in Mar. Figure 9 shows the beam spectrum with first and second synchrotron sidebands. In Apr 2017, the remaining 2 cavities and amplifiers became operational, which allowed operating the storage ring up to the design energy of 2.5 GeV.

Prior to the 2.5GeV operation, all four cavities had been re-baked out again at 120 °C for 48 h. The coupling of the cavities had been set to 1.6 measured by a NA.

For conditioning, a Mat-Lab code had been written for the D-LLRF following the Elettra RF conditioning procedures; 10Hz pulse frequency, initial pulse width 1ms increased by 0.1ms every 5s up to CW operation and return back with a higher cavity voltage.

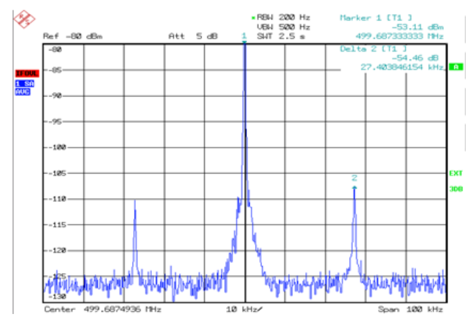

Figure 9: Beam spectrum with synchrotron sidebands.

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